INFO0064 - Embedded Systems
Examination session of January 2016

Notes or documents of any kind forbidden. Duration: 3 h 30

Each question must be answered on a different sheet with your name and section.

1. [*4 points*]
   (a) Give an example of an embedded programming problem that cannot be satisfactorily solved using the round-robin with interrupts architecture.
   (b) Can a non-schedulable set of periodic tasks have a processor load factor strictly less than 100%? If yes, provide an example of such a set of tasks. If not, give a proof of this statement.
   (c) Would it be possible to develop a real-time operating system for a processor architecture that does not have an interrupt mechanism? Justify your answer.
   (d) What is a Zeno hybrid system?

2. [*3 points*] In the framework of periodic tasks scheduling, prove that a critical instant for a task occurs when a request for this task coincides with simultaneous requests for all tasks with a higher priority.

3. [*6 points*] In order to showcase its new family of microcontrollers, a semiconductor manufacturer wants to publish an application note showing how to build a homemade digital oscilloscope.

   This oscilloscope has two analog input channels, four digital logic input channels, a LCD screen for displaying signals, a serial connection for sending data to a computer, and some control buttons. There is one button for switching between digital and analog modes, and another one for choosing between displaying the current signals on the screen, or sending these signals to the computer via the serial connection. By pressing two additional buttons, one can also modify the current voltage and time scales.

   - The microcontroller is only able to perform a single A/D conversion at a given time. (In order to acquire both analog input channels, it is thus necessary to sample them one after the other.) Such a conversion takes at least 12 μs, and triggers an interrupt upon completion.
   - In order to sample the digital inputs, the microcontroller reads the values on the corresponding pins every 10 μs.
   - Processing acquired data before displaying it needs at most 4 *ms* of CPU time.
   - The screen contents have to be refreshed at least 20 times per second, and each refresh takes 3 *ms*.
   - Sending acquired data via the serial connection takes 5 *ms* and must be done 20 times per second.
   - Buttons are checked at least 25 times per second.

(a) What is the best software architecture for this system? (Carefully justify your answer.)

(b) Using pseudocode, give the global structure of the embedded software for this digital oscilloscope.

4. [*7 points*] A smart traffic light system is installed at the intersection of two roads (cf. Figure 1). There are three stop lights $\{1, 2, 3\}$ that can either be red, green, or orange. The state of 2 and 3 is identical at all times.

   Traffic lights 2 and 3 are red and traffic light 1 is green as long as there are less than six cars waiting in front of 2 or 3. When this threshold is reached, stop light 1 becomes orange for 5 seconds before switching to red. At this time, stop lights 2 and 3 become green for 15 seconds. After that delay, they change to orange for 5 seconds and then switch to red as traffic light 1 becomes green again.

   The incoming flows of cars at the three traffic lights are respectively $f_1 = 30$, $f_2 = 6$ and $f_3 = 3$ cars/minute. We also define the saturation flow of a traffic light as the rate of cars that are able to cross this light when it is green. The saturation flows of the three lights are respectively $s_1 = 1.5$, $s_2 = 0.5$ and $s_3 = 0.5$ cars/second.

   (a) Construct a hybrid system that models this traffic management system.

   (b) Give the first 3 steps of the space-state exploration of this system, when initially no cars are queueing in front of the traffic lights, and stop lights 2 and 3 are red while 1 is green.

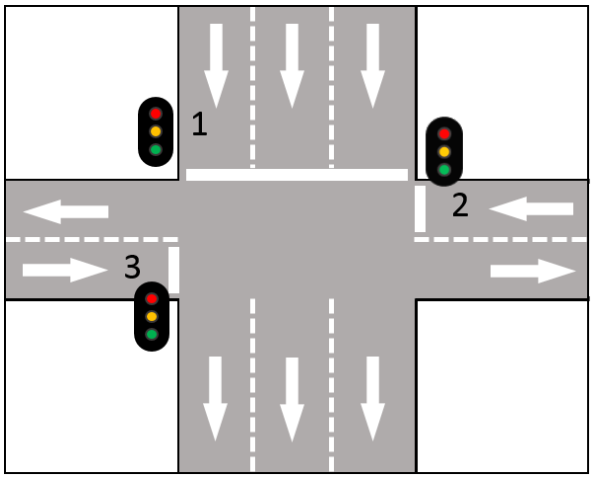

Figure 1: Illustration of the road intersection, traffic lights, and driving directions.